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A Study on Compressive Strength and Water Absorption Behaviour of Coconut Coir and Coconut Shell Powder Reinforced Natural Composites

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Abstract- In this study an effort is made to resolve the current ecological problems by using coconut coir fiber and coconut shell powder as reinforcements in the preparation of composites instead of using synthetic fibers.
In the present study the coconut coir fiber and coconut shell powder are subjected to an chemical treatment using Hydrochloric acid (HCL) and then composites are prepared by mixing the reinforcements with polymer matrix. After the preparation the composites are subjected to compression and water absorption tests. In both tests the chemically treated composites performed well as compared to un-treated composites. From the results it concludes that the chemical treatment enhances the properties of composites by increasing interfacial adhesion between reinforcements and matrix.

Index Terms- Natural composites, coconut coir, coconut shell powder, epoxy, chemical treatment.

1. INTRODUCTION

There is an emerging potential for natural fiber composites to become future replacement of many conventional materials such as metal or plastic in product application. Among the general advantages of these natural fiber composites include low density, low cost, high toughness, and reasonable specific strength, recyclability and biodegradability [1]. It is, therefore, important to characterize and improve the strength properties of the available natural fiber and to search out new sources of applications of these fibers in composites [2].

Natural fibers, such as flax, cordenka, hemp, jute, ramie, kenaf, bamboo, caraua and sisal, have been employed as reinforcement to prepare green composites and are basically composed of cellulose, hemicelluloses and lignin [3]. In this sense, biodegradable fibers like coconut have taken a growing importance for economical and environmental reasons [4].

Natural fillers reinforced materials offer many environmental advantages, such as reduced dependence on non-renewable energy/material sources, lower pollution and greenhouse emission [5]. Natural filler possess several advantages compared to inorganic fillers, that are lower density, greater deformability, abundance and low cost, less abrasiveness to equipment. More importantly, lignocellulosic-based fillers are derived from renewable resources [6].

In this study compressive strength and water absorption behaviour of coconut coir and coconut shell powder is evaluated with an aim to resolve the current ecological problems caused by using synthetic fibers in the production of composites.

The performance and properties of composite materials depend on the properties of the individual components and their interfacial compatibility. To ensure appropriate interfacial interactions their surface properties must be modified accordingly [7]. In order to minimize the poor compatibility between hydrophobic thermosets and hydrophilic natural fibers, and to improve the mechanical properties of these composites, chemical treatments have been considered as a better solution to modify the fiber surface in order to obtain better adhesion between the fiber and the matrix [8]. Chanakan Asasutjarit, et. al., studied the efficiency of coir as reinforcement in coir based green composites by pre-treating the coir. From the study it has been shown that pretreated coir was effective to remove the impurities on the surface, and performed better in mechanical properties testing than untreated coir-based green composite [9].

2. MATERIALS AND EXPERIMENTATION

2.1. Coconut coir

Coconut (Cocos nucifera) is a member of the palm family. The coconut palm is used for decoration as well as for its many culinary and non-culinary uses; virtually every part of the coconut palm has some human use [10]. Coir fiber is also a natural fiber and obtained from the outer shell or husk of the coconut, These fibers are used to make brushes, floor mates, heavy cord, coarse nets, etc. Cellulose is the main constituent of this fiber (43%) [11].The coir fiber industry is particularly important in some areas of the developing world. India, mainly the coastal region of Kerala State, produces 60% of the total world supply of white coir fiber. Sri Lanka produces 36% of the total world brown fiber output [12].

The coir fiber was obtained from coconut fruit by separating the nut from husk manually. Then coconut shell is subjected to retting process by simply dipping in water for few days. Then fibers are got loosened and cleaned. Finally obtained fibers are cut into small fibers of about 6-8mm dimension to prepare composites. The density of coir is found to be 1.2 g/cm^3.

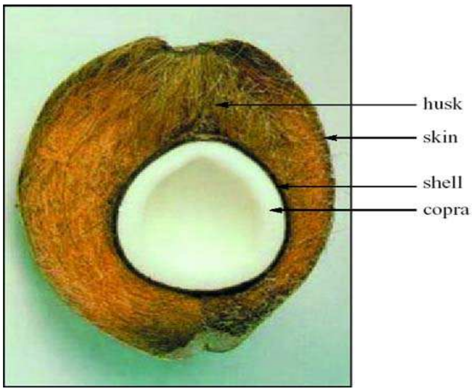

Fig.1. Cross section of coconut [13]

Fig.2. Chopped coir

2.2. Coconut shell powder

Natural lignocellulosics such as coconut shell powder (cocosnucifera) has outstanding potentials as reinforcement in plastic. Coconut shell is important filler for the development of new composites as a result of its inherent properties such as high strength and high modulus [14]. Coconut shell has high lignin content when compared to other shells, it gives product with good durability. Coconut shell has advantages such as low cost, environment friendliness, abundant availability and renewable nature [15].

The obtained coconut shells are cleaned to remove the husk and small fibers which are remained on the shells. The cleaned shells are then cut into small pieces and dried in sunlight for 7-8 days to remove the oil content. Then coconut shell pieces are converted into powder form by pounding method. Then obtained powder is divided into 104-211 µm grain size by using respective sized sieves. The density of coconut shell powder is found to be 1.60 g/cm^3.

Fig.3. Coconut shell powder

2.3. Epoxy resin

Epoxy resins (ER) are one of the most important classes of thermosetting polymers which are widely used as matrices for fiber-reinforced composite materials and as structural adhesives [16]. Epoxy resins are routinely used as adhesives, coatings, encapsulate, casting materials, potting compounds, and binders. Epoxy resins are also chemically compatible with most substrates and tend to wet surfaces easily, making them especially well suited to composites applications [17]. In the present work Lapox L-12 and K-6 hardener manufactured by Atul Ltd. and supplied by Yuje Marketing, Bangalore, India, is used. The purpose of hardener is to act as curing agent to cure the composites and the weight percentage of hardener used in the present work is in the ratio of 10:1. The density of epoxy is found to be 1.25/cm^3.

3. CHEMICAL TREATMENT OF COIR AND COCONUT SHELL POWDER

The major problems associated with natural fiber reinforced composites is there poor wettability, and moisture absorption hence these problems are overcome by chemically treating the fibers and fillers which modify the fiber surface and increases interfacial adhesion between fiber and matrix. In this view both coconut coir and coconut shell powder are pre-treated by using Hydrochloric acid (HCL) of 0.1 Normality for duration of 3 hours. After the treatment both coconut coir and coconut shell powder are washed using deionized water to remove the acidic residue and finally dried in sunlight.

4. WATER ABSORPTION TEST

Water absorption studies of untreated and treated coir and coconut shell powder reinforced composites were carried out in various sources of water such as River water, Distilled water and Bore well water. The initial weights of prepared composites were noted down. Then the prepared composites were immersed in bowls containing different kinds of water. After 24 hours, the composites were taken out from the bowls and wiped off with the help of dry cloth. Finally the weights of the composites were noted down and the percentage of water absorption is calculated as follows:

$$\% \text{ of Water Absorption } (M_t) = \frac{W_n - W_d}{W_d} \times 100$$

Where W_d and W_n are original dry weight and weight after exposure respectively [18]. After noting the weight the composites were immediately immersed in water again, and the same procedure was repeated after every 24 hours for 192 hours (8 days). Then finally graph is plotted between percentage (%) of water absorption and number of days.

5. SPECIMEN PREPARATION

To fabricate the specimens moulds were prepared according to the specifications of tests to be conduct. Before pouring the composite mixture into the moulds its inner surface is coated with a layer of releasing agent to avoid sticking of composite specimens to the mould walls. Then weight fractions of coconut coir, coconut shell powder and epoxy are calculated and weighed accordingly. The epoxy and hardener were taken in a container and stirred well, now chopped coir and coconut shell powder are mixed to epoxy and again stirred well for 5 minutes. Then so prepared mixture is poured into the moulds and allowed to cure at room temperature for duration of 48 hours. After curing the prepared composites were carefully removed from the moulds and finally cut according to the ASTM standards.

6. MECHANICAL AND WATER ABSORPTION TESTS

The prepared composite specimens are subjected to compression and water absorption tests according to ASTM standards. The compression test is conducted in Universal testing machine. The compression test specimen is prepared according to ASTM D695 standard and water absorption test specimen is prepared according to ASTM D5229. For better results three specimens were tested for each condition.

7. RESULTS AND DISCUSSIONS

7.1. Compressive strength of composites

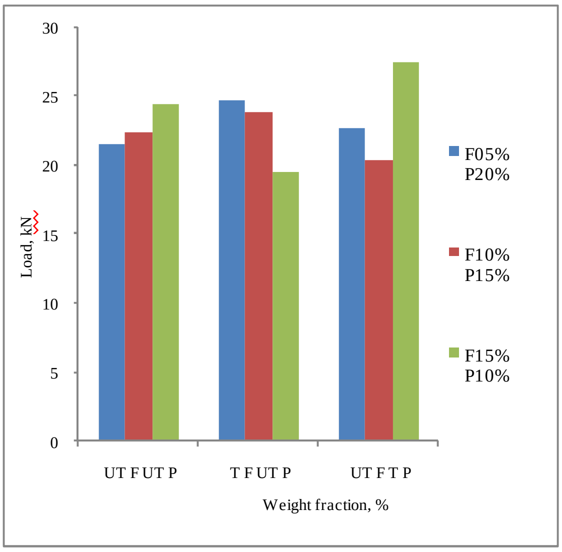

Fig.4. Comparison of compressive strength of Un– treated & HCL treated composites.

The Fig.4 Shows the comparison of compressive strength of Un– treated and treated composites for three different combinations. By referring to the figure the composite with UT F15% T P10% contains HCL-treated filler and composite with T F05% UT P20% contains HCL-treated fiber shows maximum compressive strength. The above results are better when compared to Un-treated composites. This clearly indicates that the chemical treatment of fiber and filler has positive effect on compressive strength of composites.

The chemical treatments are considered in modifying the fiber and filler surface properties as it can enhance the bonding strength between fiber, filler and matrix, due to differential hydroxyl group and also can reduce water absorption of the natural fiber [19].

The composite with UT F15% T P10% shows maximum load. It indicates that the improvement in the compressive strength of the composite is also due to increase in coir fiber content.

It was mainly attributed to the increased stress transfer from the polymer matrix to the coir fiber. In addition, increasing the coir fiber content suggested a uniform stress distribution from the polymer matrix to fibers [20].

7.2. Water absorption test

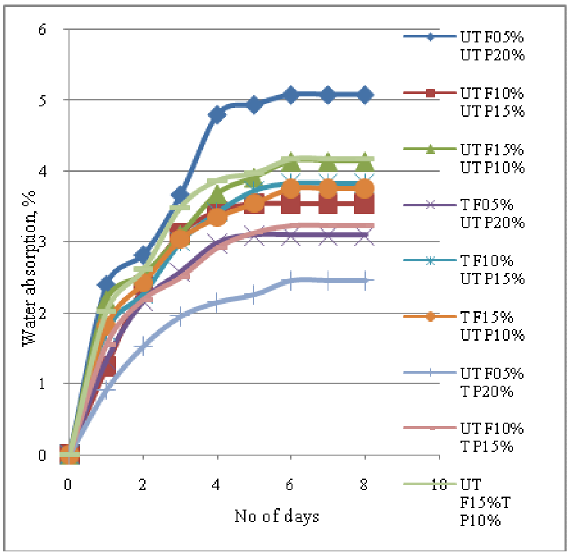

Fig.5. Comparison of % of water absorption of untreated & HCL treated composites in bore well water.

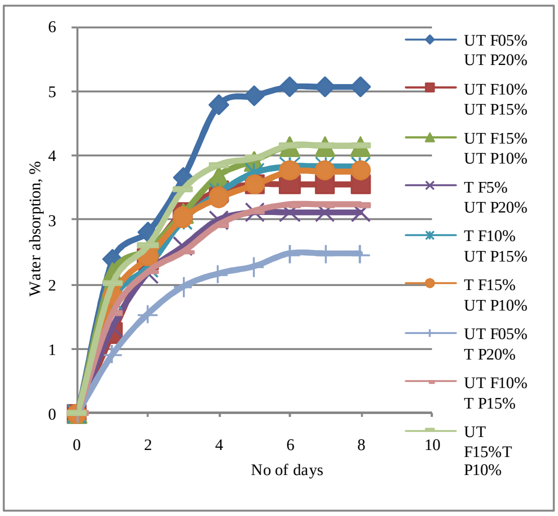

Fig.6. Comparison of % of water absorption of untreated & HCL treated composites in river water.

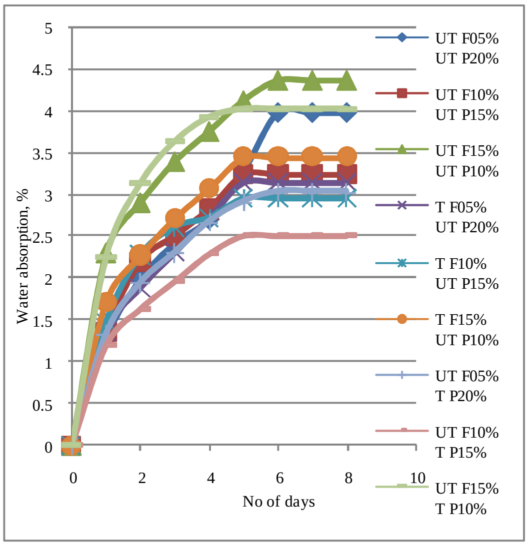

Fig.7. Comparison of % of water absorption of untreated & HCL treated composites in distilled water.

Fig. 5, 6 and 7 shows the water absorption test results for bore well water, river water, and distilled water respectively. From all the figures it is observed that the chemically treated composites absorb less water as compared to untreated composites.

It is due to the hydrophilic nature of fiber that causes the water uptake by the lignocellulosic materials. It is known that lignocellulosic fiber absorbs water by forming hydrogen bonding between water and hydroxyl groups of cellulose, hemicellulose and lignin in the cell wall [21]. The chemical treatment improves fiber-matrix adhesion largely by introducing polar or excited groups or even a new polymer layer that can form strong covalent bonds between the fiber & the matrix, & sometimes by roughening the surface of fibers to increase mechanical interlocks between the fiber and the matrix [22].

8. CONCLUSION

The compressive strength and water absorption behaviour coconut coir and coconut shell powder reinforced natural composites have been studied and discussed here, from this study the following conclusions can be drawn:

- The chemical treatment affects the both compressive & water absorption behaviour of composites.
- The chemically treated composites exhibited better compressive strength and low water absorption as compared to Un-treated composites.

- The Compressive strength is identified to be maximum in HCL-treated filler composite with UT F15% T P10%.
- The both HCL-treated fiber and filler composites exhibits low water absorption than un-treated composites.
- Finally from this study it is concluded that the chemical treatment enhances the compressive strength of composites and show low water absorption behaviour.

ABBREVIATIONS

F	Fiber (Coconut Coir)
P	Filler Particle (Coconut Shell Powder)
UT F	Untreated Fiber
UT P	Untreated Filler Particle
T F	HCL Treated Fiber
T P	HCL Treated Filler Particle
HCL	Hydrochloric Acid

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